Plain English Summary

Index measures for oak decline severity using phenotypic descriptors

Oak decline syndromes such as Acute Oak Decline (AOD) and Chronic Oak Decline (COD) are an increasing threat to native oak trees in the UK. With this comes the need to develop more quantitative, sensitive and standardised methods for visually characterising and measuring the health of oak trees.

We have developed and published protocols for measuring specific visual traits describing the health status of an oak tree. A set of visual descriptors (visual traits) were selected such as tree height crown radius and crown condition. The presence or absence of stem bleeding and visual evidence of root pathogenic fungi was also noted. The sampled trees were either considered to be healthy or had previously been diagnosed with either AOD and COD syndromes, ensuring coverage of a spectrum of know health statuses of oak.

Visual measurements were collected from a total of 174 English Oak trees, surveyed from 9 sites across England. Using these measurements and machine learning, we developed two index measures that allow us to quantitatively describe and differentiate the continuous spectrum of acute and chronic oak decline severity. The derived machine learning models were able to learn the complex interactions between the visual descriptors and predict the health condition of the trees.

The two decline indexes were:

- **Phenotypic Decline Index (PDI)**, a measure of *decline severity* with a score between 0 and 1. A more severely declining oak has a score closer to 1.

- **Decline Acuteness Index (DAI)**, a measure between -1 and 1, *differentiating between acutely and chronically declining oaks*. Acutely declining trees having a score closer to 1 and chronically decline trees a score closer to -1.

It was shown that oak trees scoring highly on the PDI scale had smaller crowns that were in poor condition. The descriptors crown size and stem bleed prevalence contributed highly towards differentiating between the acute and chronic oak decline syndromes on the DAI scale.

The decline indexes are simple but sensitive measures of oak decline severity, that can allow the comparisons of trees both across the landscape and over time. These have the potential to provide powerful tools for monitoring oak forest health and in guiding

management intervention strategies. The further development and refinement of the indices would benefit from application and testing across both local and international sites.

An interactive web application accompanying the article is available at https://jasenfinch.shinyapps.io/decliner/. The *pdi* software package for the R statistical programming language is available from the Comprehensive R Archive Network that provides a toolkit for generating these phenotypic indexes. See https://CRAN.R-project.org/package=pdi) for more information.